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Fibre use, net calorific value, and consumption of forest-derived bioenergy in British Columbia, Canada

Caren C. Dymond, Adam Kamp*

Ministry of Forests, Lands and Natural Resource Operations, Government of British Columbia, PO Box 9515 Stn. Provincial Government, Victoria, B.C. V8W 9C2, Canada

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ABSTRACT

The lack of data about current bioenergy production in British Columbia severely limits stakeholder analyses of the true value and growth potential of bioenergy within the province and the forest industry's sustainability. Fifty-two facilities were surveyed to gather statistics on rates of fibre use for energy, thermal and electrical energy capacity and net production. We estimated that from 2000 to 2011, on average 9.4 Mt of wood fibre (oven-dry) was used annually to produce energy, which was about one-third of the total harvested biomass. However, bioenergy does not drive the harvest. Bioenergy uses residual fibre from other operations—primarily black liquor from pulp mills. In total, the forest sector produced approximately 118 PJ of thermal and electrical energy in 2011, based on the net calorific value provided by respondents. Based on these results, we concluded that wood-based bioenergy supplied approximately 10% of British Columbia's energy demands in 2011. Forestry sector commodity and economic statistics likely underestimate the more than 640 M$ worth of energy it produced. The survey results also showed a wide variation in the efficiency of energy production between different facilities. Given the large discrepancy between the theoretical high heating values and what the producers achieved, it may be prudent to use an operationally-derived net calorific value or low heating value for estimating energy supply from biomass, especially for policy or business development.
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1. Introduction

Forest-based bioenergy has been presented as a potential revenue source for a struggling industry [1] and an opportunity to increase renewable energy supply by various agencies across Canada and globally. The Government of British Columbia, Canada, emphasized bioenergy in the 2009 Energy Plan, and subsequent requests by BC Hydro (an electricity utility corporation owned by the Province) for proposals from bioenergy producers indicate growth in bioenergy in the near future. These documents assume that British Columbia (BC) has the capacity and potential to greatly expand bioenergy production because the province has extensive forests (550,000 km^2 [2]). However, there is little information available on the availability of feedstock supplies and the existing production of bioenergy. For example, estimates of the production and surplus of residues from forest product

* *Corresponding author*. Tel.: +1 778 747 2727.
E-mail addresses: Caren.Dymond@gov.bc.ca (C.C. Dymond), kamp.adam@gmail.com (A. Kamp).
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manufacturing range by millions of tonnes, and one attempt to estimate the flow of harvested fibre into commodities revealed that 33% of the harvested fibre is unaccounted for in traditional commodity statistics and manufacturing studies [3,4]. Although pollution control regulations to reduce aquatic and marine damage from release of black liquor have been in place since the late 1970s and air pollution controls on burning since the mid-1990s, there is no public information on where those residues end up. This lack of data severely limits government, industry, and other stakeholders' analyses of the true value and growth potential of bioenergy and the sustainability of the forestry sector.

Current literature indicates that bioenergy is a growing and important component of lumber milling and paper production in North America and Europe. On average, the Canadian pulp sector is estimated to produce 57% of its own energy consumption from biomass [5]. In the United States in 2002, 98% of wood residues within the forest product sector were being used, largely for bioenergy [6]. In 2004, European pulp mills produced 639 PJ of energy, which accounted for 50% of the energy demand of the sector and represented 27% of total bioenergy production in the associated countries [7].

Bioenergy is also a growing source of energy for many countries in the European Union. In 2009 and 2010, bioenergy was a significant source of thermal energy in Sweden: bioenergy supplied 22% of the total energy in the country, the third largest supply after oil (32%) and nuclear power (27%) [8]. Finland was the first developed country that derived a significant proportion of its electrical energy from biomass. In 1995, it derived 10% of its electrical energy and almost 18% of its total energy from biomass [9]. In comparison, in Canada, bioenergy provided an estimated 3% of the energy supply in 2007 [10].

The bioenergy information that exists for BC is primarily capacity data, and those estimates vary. The Canadian Bioenergy Association and the Canadian Industrial Energy End-use Data and Analysis Centre estimate energy capacity for the pulp sector in BC at approximately 136 PJ y^{-1} [11]. However, according to Statistic Canada's production numbers, pulp and paper mills in BC produced more than 194 PJ of energy in 2010 [12]. These numbers suggest that production is about 143% of capacity. Other organizations provide capacity data, but there is wide variance among the different reports. In addition, many of these data sources do not give facility-level data, or estimate the amount of fibre consumed in BC to produce bioenergy, or describe the source of that fibre. At least these three types of information are needed to gauge the amount and nature of bioenergy production in the province. Once those data become available, it will be easier to assess the current and potential use of fibre for different commodities for the industry, investors, consumers, and policy makers. Furthermore, compiling these data will enable forest industries around the world to assess their products and efficiencies in comparison with BC and globally as data availability grows.

Given the noted discrepancies between production and capacity in BC, it is unlikely that national-level statistics, at least for Canada, include all the bioenergy that is produced and consumed within the forest industry. If the Canadian experience is repeated around the world, current global energy use and renewable energy production may be significantly underestimated. This underestimation is acknowledged by the International Energy Association, which requires statistics to exclude the consumption of thermal energy by the producing facility [13]. However, it does request separate estimates of thermal energy consumption by producing facilities, while acknowledging the difficulty in obtaining those estimates, in particular for bioenergy.

The lack of wood fibre consumption and bioenergy production statistics also limits the ability to estimate greenhouse gas emissions and therefore opportunities to mitigate climate change. Combustion of biomass produces carbon dioxide and methane, both of which are greenhouse gases. Some or all of those emissions are taken up over time as the forest regrows. Improved modelling and tracking of fibre use, including combustion [4] and forest carbon dynamics [14], allows climate change mitigation scenarios and options to be modelled for the combined forestry and forest products sectors [15].

Statistics and flows of wood fibre for use in different products, including biofuels are available in some parts of the world, e.g. Finland [16] and the EU [17]. In Finland, these statistics are compiled annually by The Finnish Forest Research Institute where energy production is treated as a forest industry product along with pulp or particle board [18]. In contrast, for the broader EU, the flow of wood fibre into energy and trade in biofuels has been largely uncharted until recently [17]. Their study relied on forest product statistics from the Food and Agriculture Organization and EUStat however those statistics only include wood fibre as a fuel in firewood or charcoal form and do not include energy as a forest product [19]. The renewable energy statistics provide more information, but the fuel is not necessarily specified to the forest industry or to a particular type of facility within the industry (i.e. pulp mills), e.g. Ref. [20]. This may limit the application of the data to the scale of the EU rather than local or national scales.

Traditional forest product commodity statistics do not account for about one-third of the harvested biomass in BC and available local and international information indicates that bioenergy is likely a significant part of the forestry industry, but data are incomplete and inconsistent. Therefore, the purpose of this study was to survey all forest-based bioenergy facilities in BC to quantify their energy production and consumption 1990 to 2011. Specifically, our objectives were to gather data on fibre-use (quantity and types of feedstock), annual energy production (thermal and electrical), capacity (thermal and electrical energy), use of the energy (consumption on site, sold, vented), and net calorific value (quantity of energy produced per tonne of wood fibre). Where only partial historical data were available from the surveys, we estimated the missing data for pulp mills because they were the largest energy producers. Where the respondents could not provide an operational net calorific value we used a benchmark for the industry based on information from other respondents. Our hypothesis was that approximately 33% of the harvested biomass was used for energy, based on the gap between harvested biomass and forest product commodity statistics in Dymond [3]. We collected provincial-scale supply and demand data regarding fibre used for bioenergy to inform future plans, investments, and stakeholder opinions on forest management, energy, greenhouse gas emissions and climate change mitigation. This study did not consider pellets for export in the quantification of fibre for bioenergy because those data have already been collected.

2. Materials and methods

BC is about is about 950,000 km^2 and about two-thirds (550,000 km^2) of the province is forested [2]. The forests are dominated by evergreen conifer species. The main commercial species is lodgepole pine (*Pinus contorta*), which makes up about 50% of the harvest volume [2]. Secondary species in term of volume are: spruce (*Picea englemanii*, *Picea glauca* and hybrids: *Pinus englemanii* X *P. glauca*), Douglas-fir (*Pseudotsuga menziesii*), hemlock (*Tsuga heterophylla* or *Tsuga mertensiana*), and true firs (*Abies lasiocarpa* and other *Abies* spp.). In 2011, the timber harvest was 69.2 million m^3 (almost entirely sawlogs), up 9.3% from 2010.

Bioenergy facilities and forest product manufacturing plants in BC were initially contact by phone in 2012. They were identified based on government databases. Forty-eight of the 111 facilities identified as operating in the province at the time responded. Most of the facilities that did not respond were small sawmilling or shake and shingle operations that may or may not be producing energy. The respondents were emailed the survey questionnaire, and most of the subsequent communication was conducted by email. The following information was requested:

- first year of bioenergy production;
- thermal and electrical energy production for 1990–2011;
- energy production capacity;
- amount of fibre used for bioenergy production in 2011 in oven-dry tonnes;
- type of fibre used (e.g., hog fuel, pulping liquor); and
- source of the biomass

While all companies were able to provide data for 2011 and the year they began producing bioenergy, many were not able to provide historical data. Therefore, we developed methods to estimate some of the missing data. If zeroes were used for all non-reporting facilities, a biased view of the past would be given because we have commodity statistics that show the facilities were producing other forest products and documentation of boilers and other bioenergy infrastructure through company annual reports. Conservatively estimating some data through modelling provided a less-biased picture of the past.

Dollar values in this paper are in U.S. currency, converted from Canadian dollars using the Bank of Canada exchange rate of 1.000 on October 31, 2012.

2.1. *Methods for estimating historical data*

Estimations of historical data were confined to pulp and paper mills because they are currently the largest producers of bioenergy in the province (see Results section), and in the past, they were a larger part of the forest products industry than they are in 2011. Other facilities such as sawmills and bioenergy-focussed facilities are much smaller producers of energy.

Historical data were not estimated prior to the year 2000 because improvements in efficiency and fuel switching occurred during the 1990s. In the 1990s, increased environmental regulation resulted in improvements in mills that were documented in environmental impact assessments and company annual reports. Furthermore, from 1990 to 2006, BC pulp mills reduced their fossil fuel emissions by 62% [21]. Therefore, estimates prior to 2000 would have been unreliable.

Three primary methods were used to estimate historical data for different facilities. An amalgamation of the three methods was then used to maximize the number of facilities represented in the results.

The first method was applied to for pulp mills that provided data back to at least 2007. The results of the annual mill survey were correlated to the bioenergy survey conducted in this study. Every year the Ministry of Forests, Lands and Natural Resource Operations conducts a survey of mills about the inputs and outputs for manufacturing lumber, pulp, paper, and other forest products. When there was a minimum 3-year overlap between this study's survey and the mill survey, the input of fibre to pulp mills that was reported on the mill survey was correlated to the bioenergy production reported in this study's survey using a linear equation for each facility. Historical data dating back to 2000 were estimated for five pulp mills using this method.

The second method was used for pulp mills that could not provide data back to 2007 and those that have shut down. In these cases, we used the difference between the fibre input and the pulp and paper output reported on the mill survey to estimate fibre used for bioenergy. During the chemical pulping process, approximately half of the original organic chemicals remains in the pulping liquor [22] and can be used for bioenergy. The difference between the input of fibre and the output of pulp and paper should approximate the amount of organics left over in the pulping liquor. This method did not take into account the hog fuel that pulp mills consumed because those data were not collected by the mill survey. This method estimated fibre consumption for two operational pulp mills that provided data for only 2011 and four mills that produced bioenergy in the past but have shut down. For the closed mills, the benchmark net calorific value was used to convert fibre to energy. For the other two mills, we used the 2011 net calorific value they provided.

The third method was applied to one pulp mill that reported the amount of fibre it consumed for bioenergy on a daily basis in 2011. The mill stated that its daily bioenergy production had been quite consistent over the previous four years. Because the mill survey reports the number of days each mill operated each year, bioenergy production for this mill was estimated for 2007–2010 by combining these two sources of information.

The estimates for the 12 mills were combined so data could be estimated for as many pulp mills as possible. Fig. 1a shows how these estimates added to the survey results to provide a total amount of fibre consumed for bioenergy. Further references in this paper to total fibre use or bioenergy production are referring to the survey results plus estimates. Results are presented for 52 facilities: the 48 that responded to the surveys

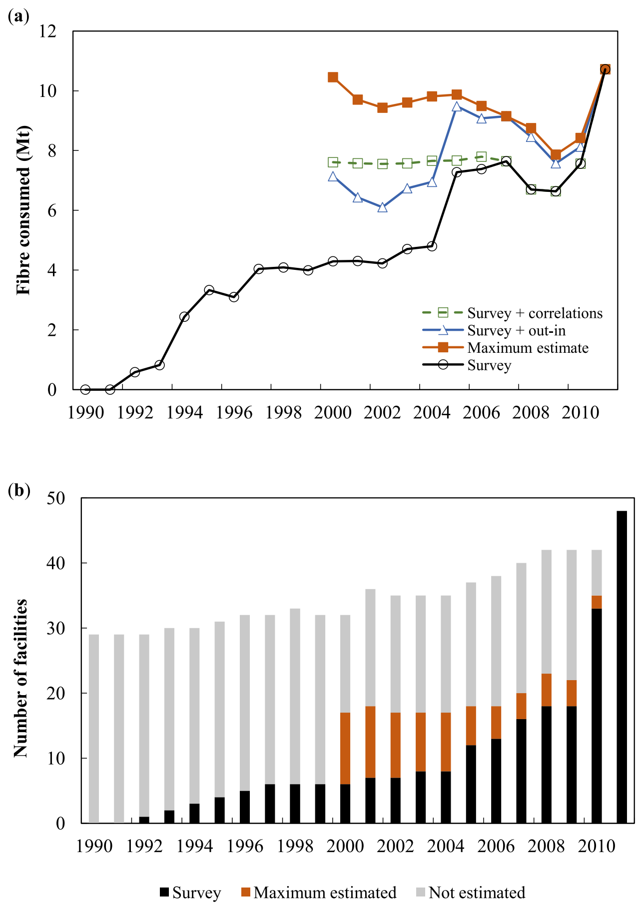

Fig. 1 – Estimates of wood fibre use for bioenergy (a), and the number of facilities producing bioenergy (b) in British Columbia from 1990 to 2011. Different lines and fills indicate results based on survey responses only (Survey), or the survey plus estimates modelled based on other available data for pulp mills. See Methods section for details. Bioenergy facilities that were operational but no data were available are denoted by the grey bars.

and four mills that were closed in 2012 but we estimated their historical data.

2.2. *Benchmark net calorific value*

In this study, net calorific value was defined as the amount of useable energy produced based on the amount of fibre consumed as provided by survey participants. This is slightly different from the International Energy Association definition: "the net calorific value of a fuel is the total heat produced by burning it, minus the heat needed to evaporate the water present in the fuel or produced during its combustion" [13]. Or the textbook definition that the net calorific value "measures the heat release with water in the vapour phase" [23]. Rather than focus on a theoretical value that depends on knowing the species, degree of decay, and moisture content of the wood [24], this study focuses on the operational realization of produced energy. A standard benchmark of 65% of the high heating value (HHV) of the fuel was used when companies were unable to provide information on both fibre consumption and energy production. The 65% of HHV efficiency rate was provided by one company in its survey response for 10 facilities. For HHV, we used Statistics Canada's assumption of 18 GJ t^{-1} of hog fuel or wood and 14 GJ t^{-1} of pulping liquor organics to facilitate comparison between the studies [12]. The benchmarks were used for 12 facilities in 2011 (11.7 GJ t^{-1} for hog fuel, sawdust, or shavings, or 9.1 GJ t^{-1} for pulping liquor organics).

In two of those situations, companies gave an energy production value that was greater than the HHV of wood. We hypothesized that these companies gave a total for energy production without filtering out the production from fossil fuels, or they simply applied an assumed HHV to their fibre consumption. In these two situations, we estimated energy from their fibre statistics using the benchmark net calorific value to provide a more realistic estimate of useable bioenergy production in the province.

3. Results

A substantial amount of BC's harvest is used for bioenergy. The amount of wood fibre used for bioenergy production in 2011 was reported as 10.7 Mt (Fig. 1a). In 2010 fibre use decreased considerably to 7.6 Mt—and the number of facilities reporting declined from 48 in 2011 to 32 (Fig. 1b). For the year 2000, six facilities reported fibre use of 4.3 Mt. Once the historical estimates were added, fibre consumption in 2000 could have been 7.1, 7.6, or 10.4 Mt, depending on which method was used (Fig. 1a). The average annual fibre use for energy, based on the maximum estimate, was 9.4 Mt y^{-1} from 2000 to 2011. By 1992—the earliest year that data were provided—fibre consumption for a single mill was 0.58 Mt (Fig. 1a).

From 2000 to 2011, approximately 29% of the harvested biomass (plus imports) was used for bioenergy annually (Fig. 2a). This compares with 56% per year for traditional forest commodities such as lumber and pulp ([3] updated with 2010 and 2011 data). On average, 8.2% of the harvest was exported as logs, pellets, chips, and other residuals annually. Even with the additional information on energy use, not all of the harvest could be accounted for in all years. From 2000 to 2011, the average unaccounted-for harvest (plus imports) was 5% per year. Imports accounted for only 2–4% of the total fibre supply. Bioenergy was one of the largest consumers of fibre in BC from 2000 to 2011, and consumed as much or more fibre as lumber in some years (Fig. 2b). In 2010, bioenergy and lumber were the two largest consumers of BC forest fibre: each accounted for approximately 33% of the total harvest.

The main feedstock (94%) for bioenergy in BC was derived from mill residues, either in the form of hog fuel, sawdust, and shavings (4.2 Mt), or organics from pulping liquor (5.8 Mt). Only 5% of the fibre was sourced from logging residues. However, 27% of the facilities that answered the survey reported that they used logging residues for bioenergy. One facility in particular reported that logging residues accounted for 45% of its fibre for energy production. Other companies stated that they were interested in using logging residues but could not make the economics work. The remaining fibre used was from municipal construction waste. Currently, municipal

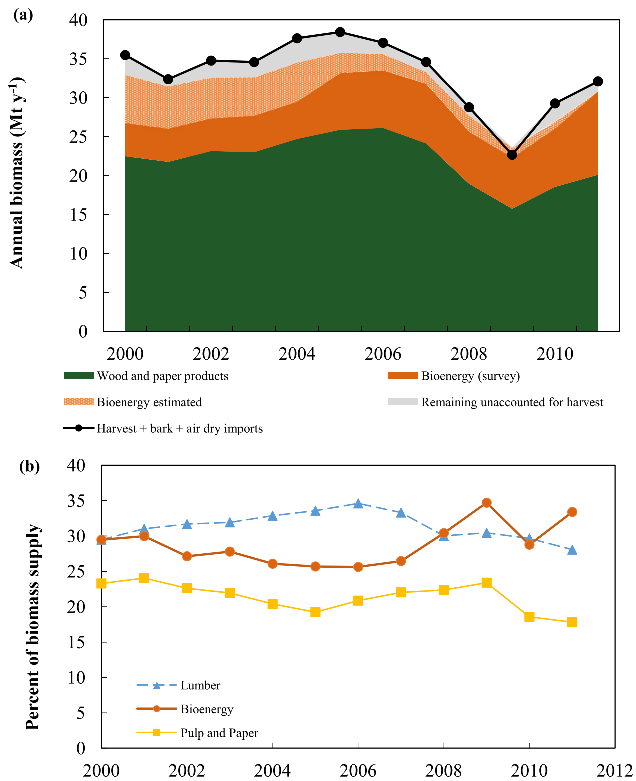

Fig. 2 – Estimates of the wood fibre used for bioenergy 2000–2011 from our study with the biomass supply (harvest, bark and imports), and wood and paper products as reported in Dymond [3] (a) and the percentage of the biomass supply that goes into the three major product categories.

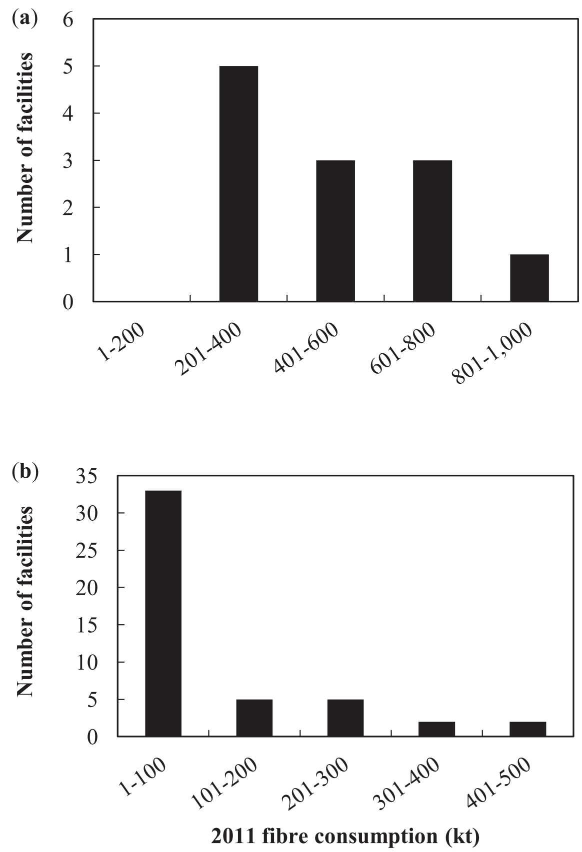

Fig. 3 – Facility size distribution by fibre consumption of (a) black liquor, or (b) hog fuel, sawdust, and shavings.

construction waste makes up a very small percentage of the fibre that is used for bioenergy.

The size (fibre consumption in 2011) distribution of bioenergy facilities differed considerably between those using solid wood feedstock and those using pulping liquor (Fig. 3). Most pulp mills (9 of 12) used pulping liquor organics for energy production. In 2011, each pulp mill consumed up to 1 Mt of fibre in the form of pulping liquor organics (Fig. 3a). Most of the facilities that consumed wood fuel were much smaller facilities; they used less than 0.1 Mt in 2011. However, there were a few large facilities in the province that consumed solid wood fuel (>300,000 t consumption).

Bionergy production was fairly stable from 2000 to 2007, with lower rates in 2008–10 and higher rates in 2011 (Fig. 4). The 2000–11 average production was 98 PJ per year.

Similar to fibre consumption, most of the energy was produced at a small number of large facilities in 2011. The pulp mills produced 86% of the bioenergy produced by the survey respondents, even though they constituted less than 30% of the respondents. Furthermore, bioenergy facilities in BC operated at about 50% of their thermal energy production capacity (Fig. 5a) and nearly 75% of their electrical energy production capacity in 2011 (Fig. 5b).

Approximately half of the electrical production was sold off site; the other half was consumed on site in 2011 (Fig. 5b).

Nearly all of the thermal energy that was created was consumed on site, while a small portion was vented (Fig. 5a). Venting occurred in a small number of mills that needed to run their boilers even if there was no use for the heat. In these situations, hog fuel was burned for waste management purposes, not energy production. In electrical power production, excess heat that is used to create electricity is sometimes vented in a cooling tower, but typically this was not estimated separately by respondents. Survey respondents indicated that

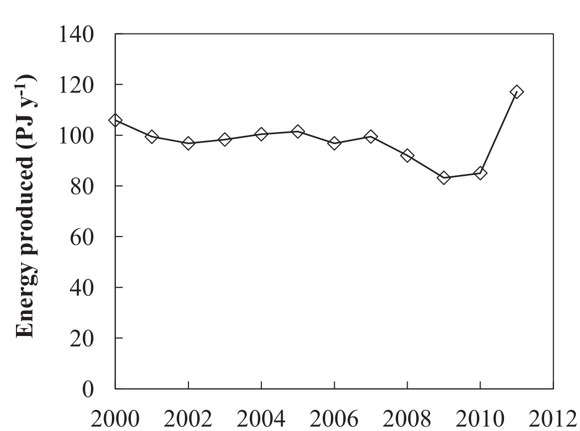

Fig. 4 – Estimates of annual bioenergy production from wood fibre in British Columbia from 2000 to 2011.

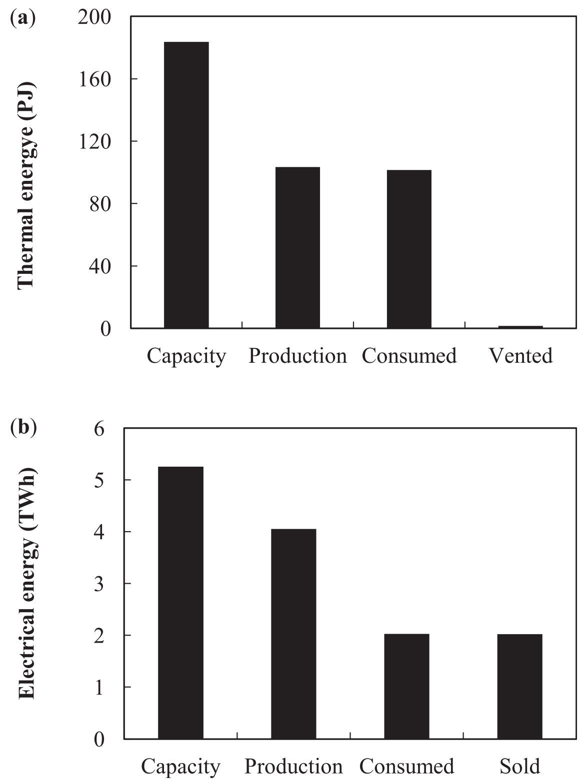

Fig. 5 – Capacity, production, and use of thermal (a) and electrical (b) bioenergy from wood fibre in British Columbia, 2011.

most of this lower quality energy (heat) could be used if a consumer was nearby.

A wide variety of net calorific values was reported within the industry (Fig. 6). In this study, net calorific value was defined as the amount of useable energy produced per tonne of fibre consumed. The electricity-focused producers reported low net calorific values (median of 5.6 GJ t^{-1}). Thermal facilities had a median net calorific value of 12.6 GJ t^{-1}, or 70% of the HHV. The range of net values for these mills was 3–16.8 GJ t^{-1}. Pulp mill combined-heat-and-power producers had a median of 11.1 GJ t^{-1} and a range of 10–14 GJ t^{-1}. Some of this variability may have been due to different interpretations of the survey questions.

4. Discussion

This study addressed one particular knowledge gap: 33% of BC's harvest had no certain end use [3]. Based on the results of this study's survey, we estimated that bioenergy accounted for most of the missing wood fibre, with an average of 9.4 Mt of fibre consumed per year from 2000 to 2011 and more than 10.7 Mt consumed in 2011. These results support the hypothesis that bioenergy is the end-use for most of the previously unaccounted-for harvest. In addition to the 10.7 Mt consumed in 2011 for local bioenergy, 1.4 Mt was exported as pellets, totalling 38% of the biomass supply. The results for 2009 were notable because total fibre use exceeded the

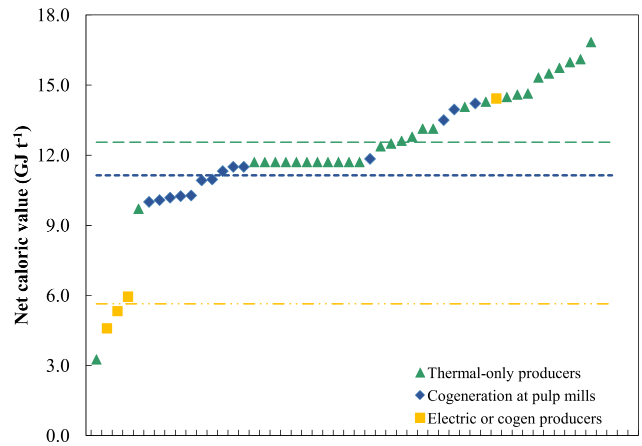

Fig. 6 – Operational net calorific value (energy produced per unit of wood fibre) in 2011 for each of the 48 facilities that responded to our survey. Lines are the median values for each facility category. There are no *x*-axis labels because each point is simply a different facility.

biomass supply by 4%. While many of the conversion factors for different products lack precision, 2009 was also the second year of a steep decline in logging rates, and therefore the availability of hog fuel, sawdust, and shavings from lumber mills. Anecdotally, facilities reported more use of logging residues for energy in 2009.

The use of these residue streams to produce bioenergy represents a significant improvement in the environmental performance of the industry. In the past, pulp mills disposed of much of their pulping liquor through effluent, while saw mills used beehive burners to dispose of their wood waste. These disposal mechanisms were environmentally harmful and wasted usable forest fibre [25]. Regulations brought in to reduce the pollution of rivers, ocean bays, and air [26], left mills with carbon-rich feedstock that has become a source of cost savings, or even revenue for those selling electricity to the grid. This shift in perception from viewing residues as a cost centre to viewing them as a profit centre is an overall benefit to the industry and to the environment.

Mills in Europe are similarly realizing the opportunity that energy production provides. For example, the Stora Enso Oyj Veitsiluoto Mills in Finland reduced the amount of waste going to landfills by 84% over 10 years, and in 2004, produced 78% of the mills' energy needs [27]. Stora sends all the solid wood residuals to the energy boiler. In addition, biosludge from the wastewater treatment plant is incinerated and the energy is captured. Surprisingly similar to the BC results, for the EU overall, Alakangas et al. [17] reported 31% of the biomass supply to the forest industry was used for bioenergy. Furthermore, other users access the forest for fuel, so overall 40% of the forest biomass supply was used for energy in 2008. Consistent with our study results and the EU forest industry results, Chen et al. [28] estimate 29% of the forest harvest was used for energy in the Canadian province of Ontario. The pulp and paper industry uses 20% if the harvest for energy, and the remaining 9% is consumed within the lumber, plywood, and panel board manufacturing mills. However, for the Canadian forestry and forest products sectors as a whole, that study estimates a somewhat lower percentage; 26% of the industrial harvest was consumed for energy [28].

A detailed survey of wood-based bioenergy producers in Scotland estimated 0.46 Mt in 2008 [29]. Scotland's annual harvest rate was only 7.6% of BC's harvest. However its wood fuel use is 9.5% of BC's use of solid wood fuel. The greater proportional use of wood fuel in Scotland is likely related to large bioenergy facilities that are not associated with the pulp and paper industry.

Overall, bioenergy is a secondary product in BC: it relies on using residual streams from other products. Although bioenergy is one of the largest consumers of fibre in the forest products sector, the results of this study indicated that trees are not being harvested directly to feed energy demands. This is a net benefit to the atmosphere because greenhouse gas emissions are being reduced [30]. The harvest is driven by the production of lumber, pulp, oriented-strand board, or plywood. By using what was previously considered to be waste, bioenergy facilities are replacing fossil fuels or reducing the demand on hydropower.

According to the results of this study, in 2011, pulp mills produced most of the bioenergy in the province. This is likely because pulp mills have a high energy demand and there is ready supply of pulping liquor organics that can be used for bioenergy. The average kraft pulp mill in Canada consumes 330 kWh of electricity and 11.3 GJ of thermal energy for every tonne of pulp created [5]. In the past, pulp mills likely accounted for an even more than the 2011 statistic of 86% of bioenergy production because fewer other facilities were producing energy. These non-pulp mill facilities are much smaller energy producers; on average, they consume 10 times less fibre for energy production than the average pulp mill.

Thermal energy and electrical energy capacities in this study were higher than those in most other reports, in part because this study included many more facilities (Table 1). The largest difference was in the thermal energy category. The results of this study indicated that in 2011, bioenergy facilities in BC created 118 PJ of bioenergy in total. Statistics Canada [12] reported BC's net energy supply in 2011 was 1018 PJ. However, this did not include bioenergy, only fossil fuel, hydro, and nuclear power. Adding the energy calculated in this study would increase the supply by about 10%–1137 PJ. This level of production had a commercial value of more than 368 M$ in terms of thermal energy and 275 M$ in terms of electrical energy (based on rates of 3.57 $ GJ^{-1} for thermal energy [31] and 108 $ MWh^{-1} for electrical energy [32]). Based on the results of this study, it is estimated that the forest industry produces more than 640 M$ worth of bioenergy which is likely not reported in forest sector statistics.

The production estimate of 118 PJ in this study is considerably lower than Statistics Canada's estimate of 194 PJ, even though this study included more than just the pulp mill facilities. One reason may be that Statistics Canada uses the HHV to calculate energy production without taking into account the efficiency of the technology the companies used, and they reported more fibre [12]. This demonstrates the drawback of using the HHV methodology for estimating production of usable energy from biomass. Statistics Canada also reported 1.7 Mt more wood fibre was used in 2011 than was estimated in this study. This difference may have been caused by respondents' interpretation of the surveys. One point that we had to clarify with pulp mills surveyed was the difference between total pulping liquor used for bioenergy and the organic component of that pulping liquor (50%).

The survey results in this study showed a wide variety of reported net calorific values within the industry; most indicated that the actual production of energy occurred at a substantially lower rate than the HHVs commonly used to estimate production and consumption rates. In this study, net calorific value was defined as the amount of useable energy produced based on the amount of fibre consumed. These results indicate that forecasts that rely on HHV are overly optimistic. It may be prudent to use an operationally derived net calorific value or a low heating value to estimate energy supply from biomass or greenhouse gas emissions. Given the variability in usage of factors to convert fuel to energy around the world, all documents on bioenergy should include the conversion factor(s) used so estimates can be compared.

The electricity-focused producers in this study reported net calorific values that were consistent with industry norms for electricity production where approximately 30% efficiency is expected [33]. The range of net values for cogeneration and thermal producers was wide, which indicates there are opportunities to improve efficiency. Although, some of the variability will be caused by differing moisture content of the feedstock from temperate coastal climates to dry, continental climates where a portion of the feedstock is from salvage of dead trees or where the feedstock is kiln-dried (e.g. planar shavings). Improving efficiencies could lead to a greater availability of fibre for other products or more energy to meet society's demands.

Table 1 – Comparison of industry characteristics from different sources for wood-based bioenergy in British Columbia.

Characteristic		This survey – all facilities 2011	CIEEDAC[a] – all facilities 2009 [11]	Statistics Canada – all facilities 2009 [12]
Number of bioenergy facilities		48	21	
Capacity (MW)	Thermal energy	5825	3767	
	Electric energy	600	544	
Annual production	Thermal energy (PJ)	103.3		
	Electric energy (GWh)	4054		1711
	Total (PJ)	118	25	201.5
	Total (GWh)	32,763	6977	55,972

[a] Canadian Industrial Energy End-Use Data and Analysis Centre (CIEEDAC).

5. Conclusion

We estimated that on average from 2000 to 2011, 9.4 Mt of wood fibre (oven-dry) was used annually to produce 98 PJ of energy per year in BC. The local use of fibre together with exported wood pellets means that in 2011, 38% of the wood fibre supply (harvest plus imports) went into bioenergy production. Energy has not traditionally been considered a forest product in BC and many parts of the world, however, these results show the importance of energy production for the sector.

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